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TA-53 Facility Management

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TA-53 Procedure

Leak Checking LANSCE Stack Sampling Systems

53FMP 104-12.1

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1.0 Introduction

The monitored stacks at the Los Alamos Neutron Science Center (LANSCE), located at Los Alamos National Laboratory (LANL) Technical Area 53,are designated TA-53-BLDG-7-ES-2 and TA-53-BLDG-3-ES-3. For simplicity, the stacks are referred to in this procedure as "ES-2" and "ES-3," respectively.

To ensure proper analysis of TA-53 stack emissions, the air samples must reach the monitoring equipment without significant dilution. This dilution would result from fresh air being mixed with the sample air stream due to a leak in the sampling system. This procedure details methodology to detect any potential leaks in the sampling system.

According to 40 CFR Part 60, Appendix A, Method 5, Section 4.1.4, "Leak Check Procedures," a significant leak rate is one in excess of 4% of the sample flow or 0.02 cubic feet per minute (whichever is less). Due to the sample flow rates at LANSCE stacks (2 cfm and above), system leak rates must be maintained at less than 0.02 cubic feet per minute (0.0057 cubic meters/minute).

Note that leak checking of stack sampling systems is NOT required under 40 CFR 61, Subpart H, which regulates radioactive air emissions from Department of Energy facilities. However, leak checking of sampling systems is considered a "good practice" and therefore will be performed prior to each LANSCE beam operating period.

2.0 Purpose

The purpose of this procedure is to ensure that LANSCE stack sampling systems are free of significant leaks. If a leak is detected prior to a beam operating period, steps can be taken to rectify the situation prior to facility operation.

3.0 Scope

This procedure applies to the particulate and gas sampling systems at TA-53 monitored stacks, ES-2 and ES-3.

A revision history of this document is contained in the following table.

Revision	Date	Description Of Changes
0	7/26/93	New document, issued as MP-7-OP-9-5.01, "Procedure for Leak Checking Lines at LAMPF stacks"
1	6/01/98	Reformatted for LANSCE-FM document control; content revised and expanded to reflect current operations; issued as 53FMP 104-12.1. Attachment 1 included to derive calculations & equations used in analysis.

4.0 Definitions

Facility operation — Memo ESH-17:96-291, "Sampling and Reporting Requirements for LANSCE," dated July 9, 1996, defines emissions monitoring and reporting requirements for TA-53. Sampling for particulate & vapor activation products must be carried out at all times. Gaseous emission monitoring from ES-3 and diffuse monitoring of the beam switchyard must occur when any beam is delivered to the switchyard or beyond. When beam is delivered down Line A, diffuse monitoring must occur for designated areas. When beam is delivered down Line D, gaseous emissions monitoring at ES-2 must take place.

5.0 Responsibilities

If you are	you will
LANSCE Radioactive Air Emissions staff	Perform all steps of this procedure in the proper time interval, or ensure that steps are performed by personnel designated by the LANSCE facility manager.

6.0 Precautions and Limitations

6.1. The internal components of the stack sampling systems may be contaminated with radioactive material. To mitigate this hazard, the time interval between the end of the *previous* beam operating period and the leak check should be maximized, still allowing sufficient time to resolve any problems that may be detected during this leak check before the next beam operating period.

6.2. Historically, there has been no detectable contamination on the probe surfaces. However, to mitigate possible contamination hazards, take the following precautions.

6.2.1. Wear gloves when removing the sample probes or breaking the sample lines prior to leak checking.

6.2.2. Verify that the stack fan is ON and providing negative pressure (suction) into the stack and not blowing stack air out onto the worker.

6.2.3. Have a radiological control technician take a swipe on the probe (or sample line internals) to verify no contamination is present.

6.2.4. Prior to performing the leak checks, consult with ESH-1 to verify the adequacy of these safety precautions. At the discretion of ESH-1, a radiological work permit (RWP) may be required to perform the leak checks.

6.3. A significant portion of the sample lines is located outside of TA-53 buildings. Thus, temperature effects can expand or contract the air in the systems and lead to errors in analysis. Avoid performing leak checks during exceptionally warm or cold periods, when such temperature effects could be significant. In all cases, be sure to include proper correction factors for stack air temperature and ambient pressure.

6.4. The “standard” leak check measures the leak rate of the entire sample line, associated gauges, sampling units, etc. This is accomplished by creating a vacuum from the tip of a sample probe to the inlet of the associated sample line pump, and monitoring the system in-leakage (pressure rise) over time. At ES-3, this is readily accomplished due to the easy access to the probes from the ES-3 stack pad. At ES-2 however, access to the probe is not simple due to the sample location near the top of the stack. The sample lines at ES-2 are therefore tested by creating a vacuum from the inlet of each sample pump to the point where each sample line exits the stack wall. This checks the majority of the system volume and associated gauges, leaving only the ES-2 sample probes outside the analyzed volume. Due to the construction of the probes, it is unlikely that leaks would occur in these areas. It is more likely that leaks would occur at the sample system gauges & valves, areas that are all within the analyzed volume.

6.5. In addition to checks of the entire system, it may be desirable at times to analyze only a small portion of a sample system. If this is the case (such as when the system setup is changed for special measurements), the methods described in this procedure can still be applied, but to a small section of the total system volume. Thorough documentation of the volume sampled and analysis steps shall be recorded in the applicable logbook for all such measurements.

7.0 Procedural Steps

7.1. Required equipment

Typically, the pump used for pulling air through the sample system can be used for the leak test. The pumps are equipped with a sample inlet valve and “fresh air" inlet valve. The sample inlet valve is used to isolate the sample volume when the proper vacuum is achieved; the fresh air inlet valve is adjusted as needed to achieve the proper vacuum. Other required equipment:

- gloves (typical latex "radworker" type) to be worn while handling probes or internal components of sample lines
- mechanical vacuum gauge, typical readout 0-100 inches of water (ES-3 systems already have gauges in-line with the system; at ES-2, a gauge and associated hose assembly must be put into the system)
- stopwatch
- thermometer (each stack has a thermometer already monitoring stack air which can be used for this analysis)
- appropriate stack logbook to record readings
- rubber stoppers to plug the system probes or sample lines

ES-3, gas system probe	#4 rubber stopper
ES-3, particulate/vapor system probe	#2 rubber stopper
ES-2; gas system sample line	#3 rubber stopper
ES-2, particulate/vapor sample line	#8 rubber stopper

- Vacuum grease to assist in sealing the rubber stoppers in the probe tips or sample line (as needed)
- Ladder to access roof of Building 7, room 200 (ES-2 stack building), if permanent ladder is not in place. Ladders can be borrowed from the Facility Maintenance shop, building 24.
- Scaffolding at the ES-2 stack, to access the sample lines. Scaffolding should be permanently in place at ES-2; if not, contact the building manager or ESH-17 (who maintain the scaffolding through JCNNM).

7.2. Describe system

- In the logbook, thoroughly describe the sampling system being analyzed.
- Draw a diagram of the system and record the volume in the logbook (if the system is identical to previous measurements, one can merely reference logbook pages rather than reproduce extensive diagrams and/or volume calculations).
- Unplug or turn off sample pump of system to be analyzed, to avoid damage to pump and sample lines while system volume is sealed.

7.3. **Remove, inspect, and seal probes**

7.3.1. At ES-3:

- Prior to removing the sample probes, don gloves to protect against possible contamination.
- Disconnect connecting devices to prepare for probe removal from the stack penetration. Verify that the stack fan is on and providing suction into the stack and not blowing out of the penetration.
- Have an RCT take a swipe of the probes immediately after they are removed to verify no contamination.
- Once the probes are removed, begin inspection. Record the probe serial number (if applicable).
- Examine the probes for excessive material buildup, cracking, or other damage. If probe appears damaged or otherwise inoperable, contact ESH-17 for advice and potential probe replacement.
- If the probe appears to be in satisfactory condition, begin the leak test by putting the appropriate stopper in the probe tip. If the stopper does not appear to seat well, a small amount of vacuum grease can be used on the stopper to make a better seal.

7.3.2. At ES-2:

- Climb to the building roof and up the scaffolding next to the stack to access the top of the sample lines, where they penetrate the stack wall.
- Don gloves to protect against possible contamination.
- Disconnect the sample line(s) to be analyzed from the stack wall penetration.
- Verify the stack is providing suction into the stack penetration.
- Take a swipe (e.g., mazzlin) around the sample pipe inlet and give it to an RCT to verify no contamination is present.
- Insert the appropriate stopper into the system, using vacuum grease if necessary to achieve proper sealing.
- No inspection of the probes at ES-2 will be performed; if inspection is desired, contact ESH-17 for probe removal and inspection.

7.4. Prepare system

If necessary, install a vacuum gauge into the sampling system (typically only needed at ES-2; ES-3 has gauges built into the system). Record the temperature of the stack air at the start of the test.

7.5. Leak check system

- Using the sample system pump, draw a vacuum inside the sample system.
- When the desired vacuum (typically 40-50 inches of water) has been reached, valve off the pump inlet and disconnect the pump power (unplug it).
- Record the vacuum pressure on the system and the stack air temperature.
- Start the stopwatch.
- Monitor the pressure and temperature over time, recording each parameter periodically.
- After 10 minutes, record the final pressure and temperature.

7.6. Calculate leak rate

The leak rate, Q_{actual}, can be calculated from the change in vacuum pressure due to leakage of air into the evacuated system (as derived in Attachment 1). A simplified form of the equation to find the leak rate is as follows (derivation is in Attachment 1):

$$Q_{actual} = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}}\right] * \frac{V_{system}}{\Delta t * 42.2} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

where:

Q_{actual}	volumetric leak rate of system, in actual cubic feet per minute.
P_{start}, P_{stop}	pressure at start and end of analysis (measured in **inches of water <u>vacuum</u>**)
T_{start}, T_{stop}	stack air temperature at start and end of analysis (converted to **Kelvin**). To convert from Fahrenheit to Kelvin, add 459.7 to the Fahrenheit temperature, then divide the sum by 1.80.
V_{system}	volume of sample system, in **liters**; measure prior to analysis, or reference past analyses, accounting for any system modifications since last measurement
Δt	time of analysis in **minutes** (typically 10 minutes)
P_{actual}	ambient atmospheric pressure, measured in **atmospheres**, during test (typically about 0.77 atm for Los Alamos, reference the "LANL Weather Machine" for more accurate data)
T_{actual}	ambient outside air temperature, measured in **Kelvin**, during test (again, reference "LANL Weather Machine" for accurate data)
42.2	[liters * inch H_2O] / [Kelvin * ft^3]. Unit conversion constant, incorporating ideal gas constant and unit conversion factors.

7.7. Acceptable Leak Rates

As detailed in Section 1.0 above, the acceptable leak rate criteria is 0.02 actual cubic feet per minute. Leak rates less than this amount are considered acceptable. If the measured leak rate is greater than this amount, check the fittings of the rubber stoppers, any loose connections between gauges and sample lines, and other trouble spots. Fix the leaks, then perform the test again. If unacceptable leak rates continue, take action as necessary to fix the leaks and bring the leak rate within acceptable parameters. Note all results and steps performed in the applicable stack logbook.

8.0 Required Records

The following records are required from this procedure:

- Documentation of system leak checks for the ES-2 and ES-3 stacks. This documentation is recorded in the logbook for the appropriate stack. Additional documentation for fixing leaks, etc., as necessary recorded in the logbooks or appropriate binder.
- Communication to ESH-17 regarding the results of the leak test at each stack and probe inspection at ES-3. This communication can be in the form of a memo or electronic mail, as appropriate.

9.0 References

- Title 40 of the Code of Federal Regulations, Part 60, Appendix A, Method 5, Section 4.1.4, "Leak Check Procedures." Referred to as 40 CFR 60.
- Memo ESH-17:96-291, "Sampling and Reporting Requirements for LANSCE," dated July 9, 1996.

10.0 Attachments

Attachment 1 — Derivation of Leak Check Calculations

DERIVATION OF LEAK CHECK CALCULATIONS

The stack sampling/monitoring systems at TA-53 have their leak rates measured prior to each beam operation period. The sample line is plugged with a rubber stopper (preferably at the probe tip) and a vacuum is drawn on the system to a desired value. The valve at the pump inlet is then closed, sealing the system. Using ideal gas law, the number of moles of gas (air) inside the system is calculated as follows:

$$P * V = n * R * T$$

$$n = \frac{P * V}{R * T}$$

where: P = pressure of system
V = volume of system being analyzed
n = number of moles of air in the system
R = ideal gas constant, 0.08206 L*atm/(mol Kelvin)
T = temperature of system

The pressure and temperature of the system is monitored over a desired time length. The number of moles of air in the system at the start and finish of analysis can be calculated from the above equations; the difference between these two values is the amount of air that leaked into the system during the analysis. From this change in the number of moles, the corresponding change in volume of air in the system can be determined, assuming "standard-conditions" of 1 atmosphere ambient pressure and 273 Kelvin. This "standard volume" change can be converted to an actual volume change using actual ambient pressure and temperature data. This actual change in volume is then divided by the time of analysis to find the actual volumetric leak rate. Finally, this actual volumetric leak rate can be compared with acceptance criteria to determine if the system has a sufficiently low leak rate. The mathematical version of this process is described below.

To calculate the leak rate, the following system-specific data are needed:

P_{start}, P_{stop}	pressure at start and end of analysis (measured in **inches of water <u>vacuum</u>**)
T_{start}, T_{stop}	air temperature at start and end of analysis (converted to **Kelvin**). To convert from Fahrenheit to Kelvin, add 459.7 to the Fahrenheit temperature, then divide the sum by 1.80.
V_{system}	volume of sample system, in **liters**; measure prior to analysis, or reference past analyses, accounting for any system modifications since last measurement
Δt	time of analysis in **minutes** (typically 10 minutes)

Additionally, the following constants and relationships will be used in the analysis

R	ideal gas constant, R = 0.08206 L*atm/(mol*K)
407	inches of water per atmosphere
22.4	liters of air per mole of air at standard temperature and pressure (STP); referred to as the molar gas volume
28.3	liters per cubic foot

As described above, the difference in moles of gas in the system is first determined. Note that while the number of moles in the system is increasing with time (leaking into a vacuum), the vacuum pressure of the system is decreasing, which leads to the sign convention described below:

$$\Delta n = n_{start} - n_{stop}$$

$$\Delta n = \frac{P_{start} * V_{system}}{R * T_{start}} - \frac{P_{stop} * V_{system}}{R * T_{stop}}$$

$$\Delta n = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}} \right] * \frac{V_{system}}{R}$$

Again, the vacuum of the system is recorded in inches of water. To balance units, the conversion between inches of water and atmospheres must be included, as follows:

$$\Delta n = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}} \right] * \frac{V_{system}}{R} * \frac{1\,\text{atm}}{407\,\text{in.H}_2\text{O}}$$

Next, using the molar gas volume at standard temperature and pressure, one can determine the corresponding change in volume of air that entered the system from this change in the number of moles. The result will be ΔV_{STP} , the change in volume at standard temperature and pressure. Also, the units of volume are converted from liters to cubic feet.

$$\Delta n\,[\text{mol}] * \frac{22.4\,\text{L}}{\text{mol}} * \frac{1\,\text{ft}^3}{28.3\,\text{L}} = \Delta V_{STP}\ [\text{cubic ft at STP}]$$

To correct the change in volume from standard conditions to actual conditions at Los Alamos, the following data are needed. These data are available from the LANL Weather Machine, maintained by ESH-17.

P_{actual}	ambient atmospheric pressure during test (typically ~ 0.77 atm for Los Alamos; check LANL Weather Machine for more accurate data during day of test)
T_{actual}	ambient air temperature during test (check LANL Weather Machine for data)
V_{actual}	volume of sample at ambient conditions.
T_{STP}	273 Kelvin, “standard temperature” of gases
P_{STP}	1 atmosphere, “standard pressure” of gases
V_{STP}	volume of sample at “standard” temperature and pressure conditions.

To convert a volume at standard temperature and pressure to an actual volume at ambient temperature and pressure, one uses a combination of Boyle’s Law and Charles’ Law, as follows:

$$\frac{P_{actual} * V_{actual}}{T_{actual}} = \frac{P_{STP} * V_{STP}}{T_{STP}}$$

therefore

$$\Delta V_{actual} = \Delta V_{STP} * \frac{P_{STP}}{P_{actual}} * \frac{T_{actual}}{T_{STP}} = \Delta V_{STP} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{K}}$$

Dividing the change in volume (actual) by the time of analysis, one calculates the volumetric flow rate, Q_{actual}.

$$Q_{actual} = \frac{\Delta V_{actual}}{\Delta t}$$

where:

Q_{actual} volumetric flow rate of system, in actual cubic feet per minute. This is the final parameter for which we are solving.

The complete solution for the volumetric leak rate, Q_{actual} , in actual cubic feet per minute (acfm) is:

$$Q_{actual} = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}}\right] * \frac{V_{system}}{R * \Delta t} * \frac{1\,\text{atm}}{407\,\text{in. water}} * \frac{22.4\,\text{L air}}{1\,\text{mole air}} * \frac{1\,\text{ft}^3}{28.3\,\text{L}} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

While the sampling systems at TA-53 are not subject to regulations in 40 CFR 60, the criteria for leak testing described in 40 CFR 60, Appendix A, Method 5 are used to determine if the sampling systems are sufficiently leak-tight. This criteria states, "Leakage rates in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, are unacceptable." Since the sample flows at TA-53 are at least 2 cfm, the criteria of 0.02 cfm is used to determine the acceptability of leak rates.

<u>Shortcuts to above equation:</u>

To simplify the formula, all the constants in the above equation (R, the pressure conversion, mole to liter conversion, and volume conversion can be combined together into a single constant, 42.2 [L * inches water]/[ft^3 * K].

$$Q_{actual} = \left[\frac{P_{start}}{T_{start}} - \frac{P_{stop}}{T_{stop}}\right] * \frac{V_{system}}{\Delta t * 42.2} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

Since the system air temperature does not greatly vary (on the Kelvin scale) during a 10 minute leak test, one can define $T_{system} = T_{start} = T_{stop}$, and this term can be removed from the initial parentheses. The pressure difference within the sample system can likewise be removed from the parentheses, and referred to as ΔP. The resulting equation for actual leak rate, in units of "actual cubic feet per minute" is:

$$Q_{actual} = \frac{\Delta P * V_{system}}{T_{system} * \Delta t * 42.2} * \frac{1\,\text{atm}}{P_{actual}} * \frac{T_{actual}}{273\,\text{Kelvin}}$$

To simplify this equation even further, one can include a typical temperature and pressure conversion factor in the constant. This typical value of the pressure & temperature correction factor can be calculated by assuming ambient Los Alamos atmospheric pressure of 0.77 atm (a typical value) and temperature of 20 degrees Celsius (293 K).

$$Q_{actual}\,[\text{acfm}] = \frac{\Delta P * V_{system}}{T_{system} * \Delta t * 30.3}$$

Again, the pressure difference is in inches of water, the system volume in liters, the system air temperature in Kelvin, and the time of analysis in minutes. The resulting flow rate is in actual cubic feet per minute (acfm).